# Energy-Positive Wastewater Treatment and Nutrient Recovery in a Combined Hydroponics and Microbial Electrochemical System

Nachiket Aparajithan Magesh[1], Khin Thandar Tun[2,3], Veera Gnaneswar Gude[1,2,3]

[1]Purdue School of Sustainability Eng. and Environmental Eng., [2]Purdue Northwest Dept. of Mechanical and Civil Eng., [3]Purdue Northwest Water Institute

## Introduction and Motivation

### Background

- Untreated wastewater effluents can raise nutrient and biomass concentrations in water bodies, causing serious harm to aquatic environments.
- However, conventional municipal wastewater treatment is energy-intensive (2% of total energy consumed in the US).
- Municipal wastewater contains up to 10x the energy needed for its own treatment.

- Hydroponics, a soil-less method of crop cultivation, can aid in and benefit from wastewater treatment.

- *This study aims to harness the untapped chemical energy in wastewater using microbial electrochemical cells (MEC) while boosting hydroponic crop growth.*

***Typical Wastewater Pollutants:***

**N:** $NH_3/NH_4^+$, $NO_3^-$, $NO_2^-$, Organic

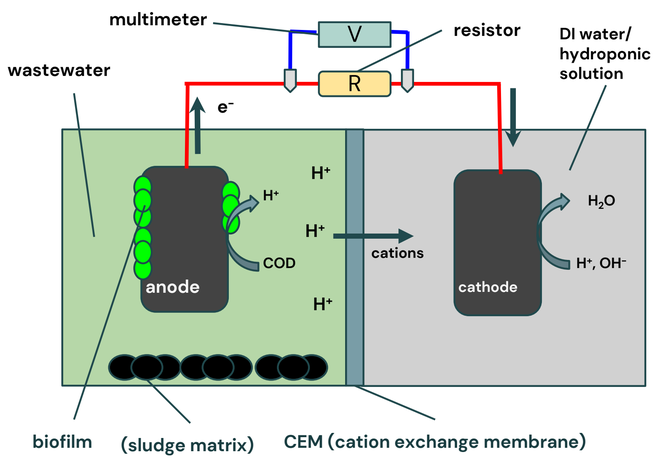
**P:** $PO_4^{3-}$, $(PO_3^-)_n$, Organic

**Oxygen-demanding chemicals**

**Suspended solids**

**Heavy metals**

### Microbial Electrochemical Cell Mechanism




- **Anode:** electroactive bacteria treat pollutants in wastewater (oxidation)
- **Membrane:** facilitates exchange of ions
- **Wires + resistor:** conducts electrons (electrical current)
- **Cathode:** completes the circuit (reduction)

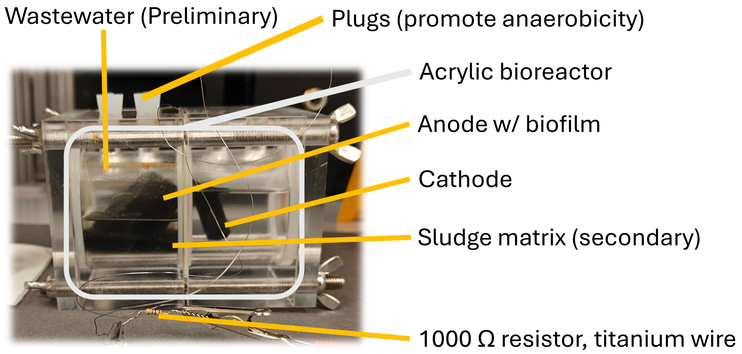
***Anion Exchange Membrane (AEM)*** Transports negatively charged ions

***Cation Exchange Membrane (CEM)*** Transports positively charged ions

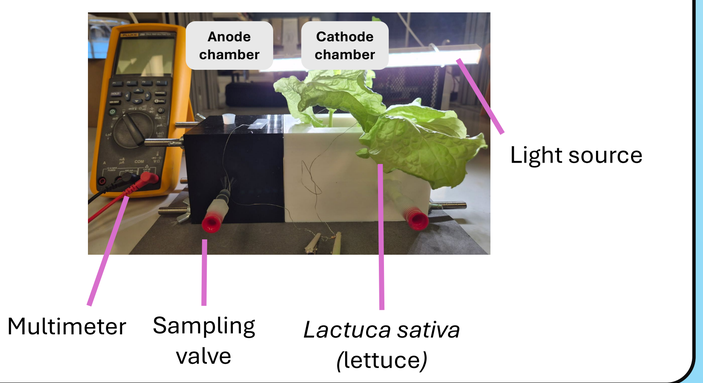
***Proton Exchange Membrane (PEM)*** Transports only $H^+$ ions

## Methods

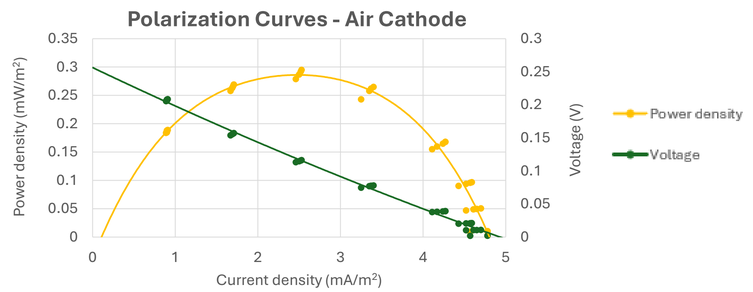
### Air cathode configuration

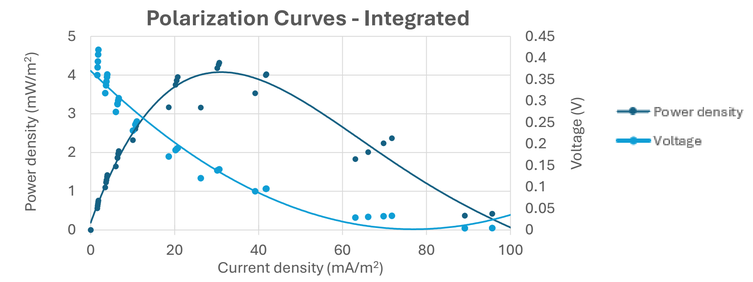



### Integrated configuration




## Results




### System Performance

**COD Removal Efficiency**
- Air cathode: 61%
- Integrated: 57%

**Total N Removal Efficiency**
- Air cathode: 54%
- Integrated: 47%

**$PO_4^{3-}$ Removal Efficiency**
- Air cathode: -15%
- Integrated: 13%

**Coulombic Efficiency (CE)**
- Air cathode: 3%
- Integrated: 12%

**Peak Voltage**
- Air cathode: 0.10-0.15 V
- Integrated: 0.16 V

**Plant Growth (% change, wet wt.)**
- Integrated: 25%

## Discussion

- **COD and total nitrogen removal rates**
  - Integrated system lower, possibly due to reduced concentration gradient and subsequently, inhibited proton exchange
  - Higher initial COD concentration correlated with higher removal
- **$PO_4^{3-}$ removal rate**
  - Air cathode: negative removal, likely due to leaching from sludge
  - Integrated: positive, likely due to osmosis from anode to cathode and improved assimilation rate by anodic biomass
- **Plant growth in integrated design:** significant decrease in cathodic total nitrogen and total phosphate suggests plant utilization of nutrients
- **Power production:** comparable potential despite using cheaper, environmentally-friendly materials

## Future Work

- Bipolar membrane (BPM) experiments
- Kinetic analysis of COD removal
- Long-term analysis of integrated system on lettuce growth. treatment times, and dominant nutrient transport pathways

## Acknowledgments

- I thank the USDA for funding this research through the REEU program.
- I thank my supervisor, Dr. Veera Gnaneswar Gude, and graduate mentor, Khin Thandar Tun, for their support for my research endeavors.

## References

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**Contact: nmagesh@purdue.edu**